High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles

DE-EE0008361 **ELT241**

Dr. Charles Zhu, Principal Investigator
Delta Electronics (Americas) Ltd
June, 2022

“This presentation does not contain any proprietary, confidential, or otherwise restricted information”

Project Overview

Timeline

- Start – December 1, 2018
- Finish – May 31, 2022
- Program extension due to COVID-19
- 98% complete

Budget

- Total Budget: $7.0 million
  - DOE Cost Share: $3.5 million
  - Recipients Cost Share: $3.42 million
- 2022 Funding Planned: $0.08M

Barriers

- System architecture and control for solid state transformer
- Medium-voltage isolation
- Power cell topology and control for high efficiency
- SiC semiconductor devices with high dv/dt and noise

Team

Lead: Delta Electronics Americas Ltd

Partners:

- General Motors
- DTE Energy
- CPES at Virginia Tech
- NextEnergy
- Michigan Energy Office
- City of Detroit

Relevance Project Objectives

- **AREA OF INTEREST (AOI) 1: Extreme Fast Charging (XFC) Systems for Electric Vehicles**
- **Delta Electronics aims to achieve objectives by the end of program**
  - To design and test a high-efficiency, medium-voltage-input, solid-state-transformer-based 400-kW Extreme Fast Charger (XFC) for electric vehicles, achieving better than 96.5 percent efficiency.
  - To demonstrate extreme fast charging with a retrofitted General Motors' light-duty battery electric vehicle at 3C or higher charging rate for at least 50 percent increase of SOC.
  - To achieve a 180-mile charge within 10 minutes.

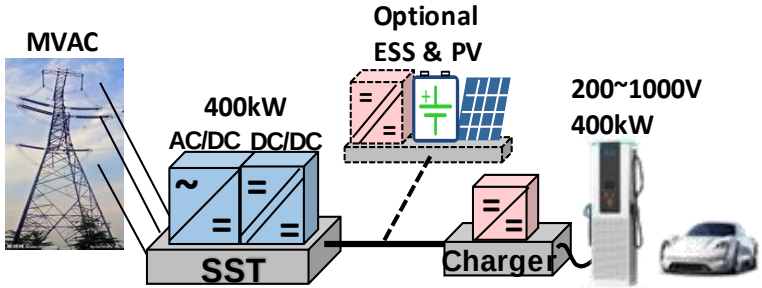
Budget Period 3 Milestones

BP3: 12/1/2020 - 5/31/2022			
Planned Date	Mile-stone #	Milestone	Achievement
5/31/2022	M3.1	Retrofit Vehicle with HVDS/RESS	Vehicle retrofit underway, expected completion in May 2022
6/3/2021	M3.2	13.2kV 400kW Lab Test	Entire operating range mapped at NextEnergy ✓
9/1/2021	M3.3	13.2kV 400kW Charging test with base vehicle	Tested with Chevy Bolt, VW iD4, Ford Mach-e Cadillac Lyric and e-Hummer ✓
5/31/2022	M3.4	Final vehicle verification and calibration with 800V vehicle.	Planned for Late May 2022

Approaches

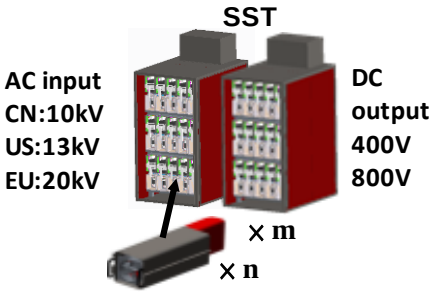
- ❑ Medium-voltage AC input, 4.8-kV and 13.2-kV
- ❑ Solid state transformer (SST)-based technology to reduce the size and weight, and to increase scalability and flexibility
- ❑ Cascaded multilevel converter topology as medium voltage interface to reduce the total number of power cell
- ❑ Multilevel resonant converter for medium voltage isolation, operated at high frequency with soft switching
- ❑ SiC MOSFET devices for high voltage and lower loss
- ❑ Interface to an Energy Storage System (ESS) and/or a renewable energy generation system (e.g. PV)

Proposed Extreme Fast Charger

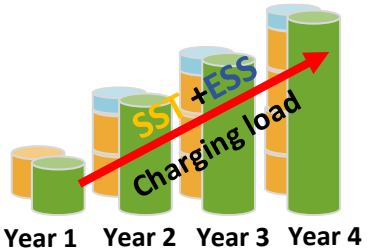


Efficiency: 97.5% × 99% = 96.5% **Increased by 3%**

Footprint: 28 ft² + 10 ft² = 38 ft² **Reduced by 50%**

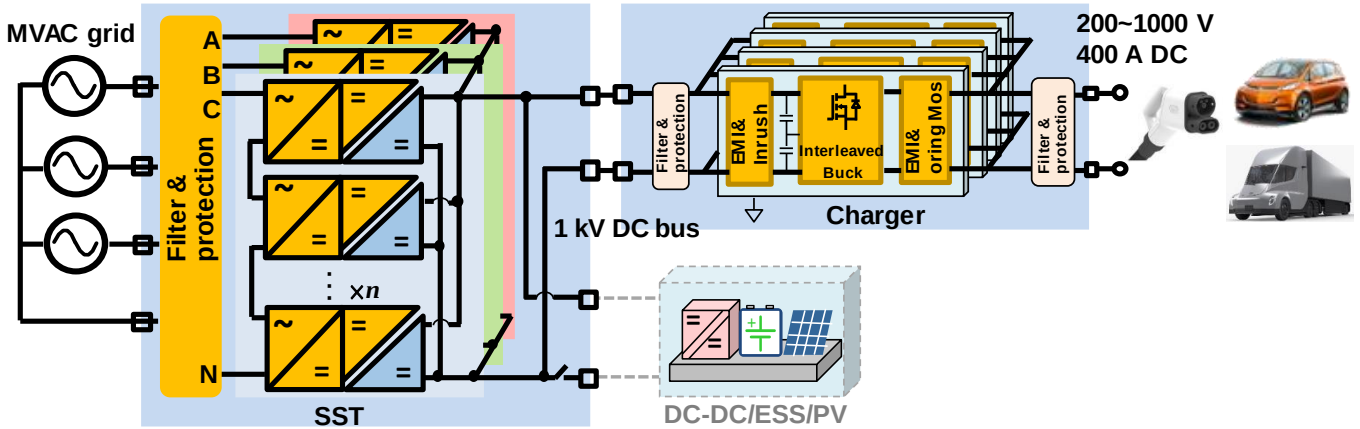


Conceptual SST based extreme fast charging station



- Modularized structure
- Scalable voltage/power
- Expandable capacity
- Lower initial cost

SST based XFC System Architecture



3-Φ MVAC input:

- 4.8kV/13.2kV
- iTHD<5%, PF≥0.98
- 60Hz±10%

SST DC output:

- 1050V±3%
- 400kW power
- Interface for ESS/PV

Charger output:

- 200V~1000VDC
- 400A max current
- SAE J1772 charging interface CCS1

XFC Specification

Power Rating	400 kW
Input AC Voltage	4.8 kV and 13.2 kV, 3-Phase, line-to-line
AC Line Frequency	60 Hz
HV Battery Voltage Range	200-1000 VDC
Maximum Output Current	Continuous 400ADC, peak 500ADC
Efficiency	Target 96.5% peak. Test result 97.5% peak.
Charge Interface	J1772 CCS1
Operational Ambient Temperature Range	-25 to 50°C
Environmental Protection	NEMA 3R (outdoor)
Additional Interface	HVDC interface (to ESS/renewable energy source)

Program Progress Update

GM 800V Engineering BEV Vehicle Build

- A Modified Cadillac SUV 800V BEV
- Characterize thermal performance during charge, discharge and propulsion modes of operation

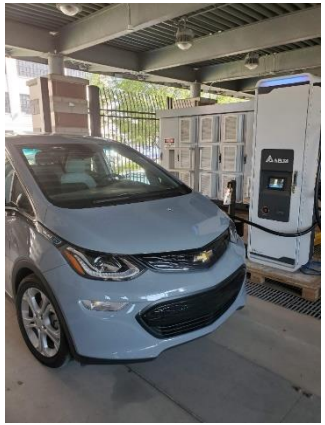
13.2kV 400kW System Test Setup

Technical Achievement:

- Completed 400kW test with e-load
- Input 13.2kVac, Output 200V-990V, 400kW,
- Peak efficiency 97.5% (exceeds target by 1%)

- Charge Dispenser User Interface

Vehicle Charging Test at Site #1



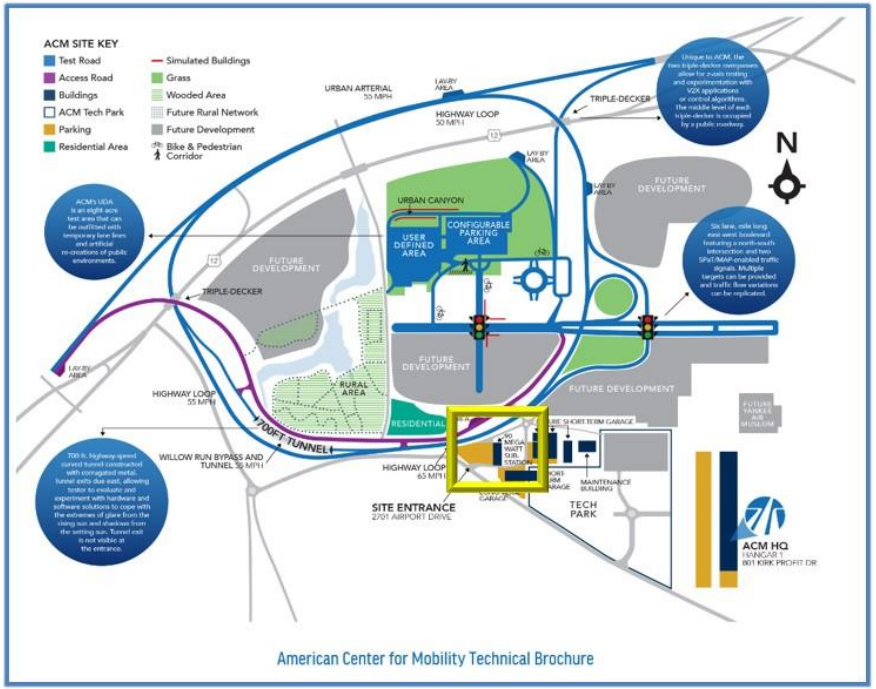
- GM Chevy Bolt

- GM E-Hummer, 800V Charging.
- GM Pre-Production Cadillac Lyric, over 400A charging. Picture not shown

- VW iD4

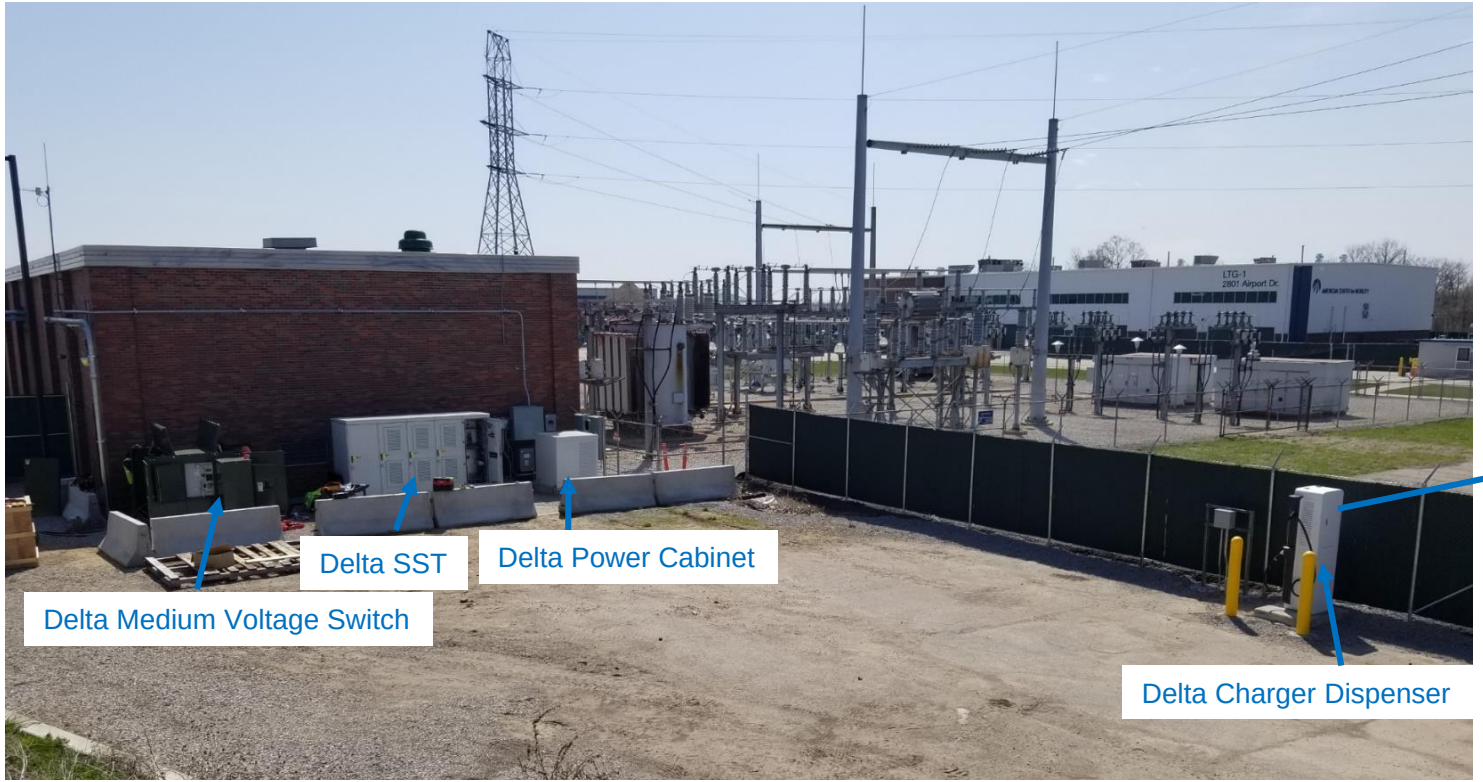
- NextEnergy, Detroit, MI

Final Test and Demo Site #2



- American Center for Mobility, Ypsilanti, MI

ACM Site Construction Update



Collaboration and Coordination

Delta Electronics (Americas) Ltd. -Primary Recipient

- Administrative responsible to DOE, single point of contact.
- Technical direction and program management (timing, deliverables, budget).
- XFC prototypes development, testing, and system integration
- Commercialization.

General Motors

- Provide a retrofit BEV capable of XFC at 800-V or higher at 3C charging

CPES at Virginia Tech

- Conduct advanced research of power stage topology for the XFC.
- Conduct advanced research of the system level control for both AC/DC and DC/DC stages.

DTE Energy

- Contribute the use of a test facility for XFC testing, vehicle charging test and demonstration.
- Consult on grid impact and operation safety, voltage specifications, standards conformance and certification.

NextEnergy

- Support XFC installation, integration, testing with battery emulator and EV, demonstration within its medium-voltage Microgrid Power Pavilion Platform.

Michigan Energy Office

- Engage state-level public sector stakeholders supporting XFC deployment.

City of Detroit

- Strengthen coordination and fostering partnerships among business, neighborhood and municipal departments.

Future Plan

April and May 2022

- ACM Test Site Completion
  - Installation of the High Voltage Switch ✓
  - Assembly of the SST and Power Cabinet ✓
- Complete the build and verify retrofit vehicle
- Test 400kW XFC system with Chevy Bolt and e-Hummer
- Test 400kW XFC system with retrofit vehicle
- Final operation demonstration

Smarter. Greener. Together.

To learn more about Delta, please visit www.deltaww.com
or scan the QR code

English

Traditional Chinese

Simplified Chinese